GEAR PUMP EXTRUDERS

FIELD OF THE INVENTION

This invention relates to an extruder for polymers and/or elastomeric materials of the kind including a gear pump having a casing in which a pair of toothed gearwheels rotate, at least one feed inlet for feeding the material into at least one intake nip between a gearwheel and a wall of the casing, and an outlet for the material. More particularly it refers to extruders used as cold or hot feed extruders for polymers and elastomers.

BACKGROUND OF THE INVENTION

The use of stand-alone gear pumps as cold feed extruders for a limited range of soft elastomers dates from about 1996 mainly for straining and calander-feeding, such as shown in DE 196 02 091 Uth; EP 0 816 049, Troester, and EP 0 857 559, Berstorff. Separately driven gear pumps as feed-devices for cold feed extruders are disclosed in EP 0 816 048, and WO 98/09792, Limper.

In "Tire Technology 1997" pp 197-198, 'Screw- or Gear Extruder - a Comparative Study', gear pumps are shown to contribute effectively to plasticizing by heat-transfer through the casing and the gears, providing about 50% of the energy in the product that way. They are shown as much more efficient than cold feed extruders for e.g. straining or calander-feeding. In the quoted example the cold feed extruder required 200 Wh/kg of drive power with a total of 154 Wh/Kg being dissipated in cooling, radiation and mechanical losses, against the gear pump needing 34 Wh/Kg as drive power plus 17 Wh/Kg for heating - a total of 51 Wh/Kg. Thus substantially only a quarter of the energy was needed for the same result, because there is practically no energy dissipation in comparison with the cold feed extruder.

Moreover, the extrusion-temperatures could be kept considerably lower and in fact almost constant with increasing rotational speed over a range from 2 to 24 rpm and proportionally rising output, while the specific power input dropped from about 110 Wh/Kg at 2 rpm to about 30 Wh/Kg at 12 rpm, remaining constant at that low level to 24 rpm. Accordingly, fully accelerated compounds could be strained, whereas for cold feed extruders excessive temperatures are the limiting factor on the output of a given size (screw diameter) of extruder. This limit varies greatly with the scorch-sensitivity of differently accelerated compounds.

In directly-fed gear pumps, it is a condition for stable functioning that the unplasticized, cold feed strip, sheet or metered pellets must be prepared so as to volumetrically substantially fit the gears of the pump within narrow limits, i.e. in thickness substantially the depth of the teeth and in width the axial length of the gears. In a gear pump the heat transfer is applied to discrete, non-flowing elements of poor heat-conducting elastomer contained between the teeth of the gear. The interior of these elements is therefore considerably less warmed up than the exterior. Therefore, directly-fed gear pump extrusion tends to be limited to uses where, as in straining or calandering, a subsequent processing device as part of its function incidentally operates to improve temperature uniformity. Gear pump extrusion is also used where the viscosity of the compound is sufficiently reduced by the low-power treatment in the pump to enable it to pass a screen at all. This factor excludes natural rubber compounds having the characteristic of "nerve" as well as other compounds of higher viscosity owing to their molecular structure and/or different kinds and quantities of reinforcement. Such compounds will either not directly feed continuously into gear pumps without being cut off by the nip of the gears or not absorb the minimum amounts of mechanical working required for plasticization. Thus many compounds e.g. as used in

the tyre industry, are not suited to gear pumps, even if these are force-fed or used in series for more work input.

Also the tendency of a gear pump to draw in air when the feed is irregular within normal tolerances leads to air inclusions in the extrudate which cannot be tolerated.

The documents referred to above attempt solutions for some of these limitations and drawbacks, involving in most cases costly mechanical complications for force-feeding and degassing.

SUMMARY OF THE INVENTION

According to a first aspect of the present invention, in an extruder of the kind set forth, at least one recess is provided in the casing wall at at least one intake nip, the or each recess extending in the direction of rotation of the gearwheel and commencing at zero cross-section prior to the nip, increasing up to the nip to a full cross-section and then having a cross-section reducing to zero within the closed transport circumference of the gearwheel, the arrangement being such that a feed strip or sheet has a continuous length of a part of its width moved through the or each recess beyond the nip into a position where another part of the feed strip or sheet is entrained within the gearwheel and is there gradually squeezed into the gearwheel whereby a cutting off of the feed strip or sheet at the nip is positively prevented.

The recess(es) will therefore maintain longitudinal continuity of the feed strip or sheet so that the nip will not cut off the feed and thereby disrupt the continuity of feeding. Further, for the average irregularities in dimensions of the feed, indrawn air will be expelled backwards into the feed inlet without any mechanical complication.

The depth of the gear teeth at the or each nip preferably corresponds to the thickness of standard feed sheet or strip or the leading dimension of standard pellets. The closer the correspondence, the better the continuity of the feed will be.

For each nip there may be more than one recess, spaced axially along the gearwheel. The recesses may be spaced along the whole axial width of the gearwheel. The width of the recesses is preferably less than half the width of the gearwheel. The angular segment of the casing containing the recess is heated to provide a reduction in friction between the feed and the casing surface. Sections of the casing containing the recesses may be removable, so that sections with recesses of different maximum cross-section can be used interchangeably to accommodate variations in the standard thickness of the feed sheet or strip.

Where the feed sheet, strip or pellets are oversized, the cross-sections of the recesses are arranged so that the total maximum cross-section exceeds the volume of material that can fill the gear teeth, whereby as the cross-section of the recesses reduces, the gear teeth will tend to be overfilled, so that entrained air and excess compound moves up the recesses to form, in advance of each nip and between the feed and the wall of the casing, a type of rolling bank such as arises in an extruder which serves to attenuate the supply of fresh feed towards a condition of equilibrium of intake and output while also expelling entrained air.

Thus, even in the case of larger irregularities in the dimensions of the feed, as will occur in elastomer sheets directly out of the mill-room, the extruder will function continuously while expelling indrawn air, without any mechanical complication and allowing the preparation of a specially dimensioned feed for the gear pump to be dispensed with. In this respect,

it should not be inferior to an extruder which has the complication of a feed-roll.

In one embodiment the feed inlet feeds a single intake nip formed between a gearwheel and the casing wall, and the non-fed gearwheel allows entrained air to escape from the region of pressure buildup on the outlet side of the gear pump where the gearwheels mesh and the material is worked. This allows air or gas to be expelled, even for less uniform feed than the recesses can de-air at the intake nip, or for porous or otherwise non-uniformed feed, or for pellets underfeeding the gear pump, or for gassing-out or moisture evaporating during transport.

Preferably, the gearwheels are of unequal diameters and the feed inlet leads to the nip of the larger gearwheel, in order to utilise this in conjunction with the casing as a heat exchanger for controlling the temperature of the material in a controlled manner. This enables an extended range of compounds to be extruded using a gear pump.

The reduction in output resulting from feeding only one gear can be compensated for, other conditions being equal, by doubling the axial length of the gear pump.

An escape passage for gas or air may be provided at a position on the circumference of the non-fed gearwheel between the pressure buildup region and the inlet.

Alternatively, at the pressure buildup region, an edge of the outlet in that part of the casing surrounding the non-fed gearwheel is provided with a projection extending towards or even beyond the common tangent to the pitch circles of the gearwheels, in order to promote the localized

filling up of a first gear tooth space in the non-fed gearwheel to provide the pressure buildup. This promotes intensive working of the material and the degassing action.

In another embodiment, the said projection is provided with a by-pass leading from the outlet to a second gear tooth-space in the non-fed gearwheel, not involved in producing the pressure buildup, whereby the second gear tooth space is filled up, with the degassing action proceeding from the second gear tooth space, and the pressure buildup between the two gearwheels is enabled to proceed as if both gearwheels had been fed.

Degassing where only one intake nip is fed leads to a separate aspect of the invention.

According to a second aspect of the present invention, in an extruder of the kind set forth, the feed inlet leads to a single intake nip formed between one gearwheel and the casing wall, and a region where the gearwheels mesh adjacent the outlet provides a region of pressure buildup of the material, with the escape of gas being through the non-fed gearwheel at the pressure buildup region.

Thus, the passage provides for escape of gas or air from the pressure buildup region even without any provision for degassing at the feed inlet. The extruder can then be used for any type of feed material, including flakes and pellets as well as sheet or strip.

The casing preferably has an escape passage for the escape of gas provided at a position on the circumference of the non-fed gearwheel between the pressure buildup region and the inlet.

The escape passage may lead to the feed inlet, or to a separate escape outlet formed in the casing.

In another embodiment the escape passage comprises a by-pass formed in a casing projection at the outlet, leading from the outlet to a gear tooth space in the non-fed gearwheel. The degassing then occurs from that gear tooth space.

Preferably, the gearwheels are of unequal diameters and the feed inlet leads to the nip of the larger gearwheel, in order to utilize this, in conjunction with the casing, as a heat exchanger for controlling the temperature of the material in a controlled manner. In the case of having to preheat the material in the gear pump, this enables an extended range of compounds to be plasticized.

In either aspect of the invention, one gearwheel may be co-axial with a screw extruder of the Transfermix type, the screw extruder being fed from the outlet of the gear pump. The outlet may extend in a direction along the said axis and be shaped analogously to that of a plate-type gear pump. The plasticizing and homogenizing action of the Transfermix assists in the extrusion of difficult compounds, including elastomers of natural rubber, highly loaded compounds and the like.

In another embodiment, with the gear pump having an outlet at right angles to the axes of the gearwheels, the outlet leads to a Transfermix extruder. The Transfermix is located in the space in which a screening device may be provided in a gear pump according to the state of the art.

The Transfermix extruder preferably comprises a stator component with helical threads, co-operating with a second component with oppositely-

handed helical threads. The second component may be stationary, or driven by the material fed from the gear pump. In either case, the homogenising and plasticizing action of the Transfermix extruder is provided in an energy-conserving manner and with reduced mechanical complexity.

Each gearwheel may be separately driven from the shafts of a gearbox carrying correspondingly-sized power transmitting gears from the drive.

The gearwheels may be cut in skew or arrow-fashion, whereby the material is moved away from one or both of the end plates of the gear pump. Then, the escape passage is provided in one or both end-plates leading from the pressure buildup region of the pump to the inlet or to a separate degassing outlet.

BRIEF DESCRIPTION OF THE DRAWINGS

The various aspects of the invention will now be described by way of example and in some detail with reference to the accompanying drawings, in which:

Figure 1 is a cross-section through a cold feed extruder comprising a gear pump, in a plane normal to the axes of the gear pump, here a vertical plane;

Figure 2 is a plan section on the line CC of Figure 1;

Figures 3A and 3B are sectional details of a view into the casing adjacent one of the gearwheels showing different embodiments of the recesses extending in the direction of motion of the gearwheel;

Figures 4A and 4B are sectional details corresponding to a plan view of Figures 3A and 3B;

Figure 5 shows a modified extruder, in which the gear pump has gears of considerably different diameters with only one feed inlet which serves the nip of the larger gearwheel only, the smaller gear serving to de-air the compound and being co-axial with a short Transfermix screw extruder;

Figure 6 shows a gear pump extruder similar to Fig 5, but modified for an outlet at right angles to the centre line of the driven gearwheel for use with a screening device, or as here shown, with a short Transfermix plasticising device without any external drive;

Figure 7 is an outside-view of the non-driven Transfermix device with a part-section showing the crossing lands of the inner and outer screens;

Figure 8 is a sectional excerpt of the intermeshing parts of the gears indicating alternative gear geometries;

Figures. 9 and 10 are a sectional elevation and a cross-section of an embodiment of a gear pump, similar to that shown in Figure. 5 but adapted to be fed with pellets or flakes;

Figure 11 shows an embodiment similar to that of Figure 10, featuring a wider feed opening e.g. to fit under the outlet of a drying machine and a special de-gassing passage extending from the non-fed gearwheel for operation under vacuum;

Figure 12, modified from a drawing in the literature on gear pumps, shows the flow-lines on the outlet side of a conventional gear pump, *in this example* with gear wheels equal in size, as a basis for understanding modifications according to this invention;

Figure 13 shows modifications to the outlet part of the casing which is adapted to having only the lower gear-wheel fed; and

Figure 14 shows another such modification providing for a by-pass to the non-fed gear wheel.

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Figures 1 and 2 show an extruder comprising a gear pump with a casing 1 in which a pair of toothed gearwheels 2, 3 are rotatable, and having a feed inlet for feeding at least one nip between a gearwheel 2, 3 and its adjacent casing wall. The casing 1 of the gear pump encloses the gears 2 and 3 which are mounted in bearings 4 in a known manner. The gear 3 is rotated through its shaft 5 by an external drive - not shown.

A divider 6 in the inlet 7 of the gear pump forms within the walls of the casing 1 two entry channels 8 for a polymeric material, one to the intake nip of each gearwheel 2, 3. The polymeric material may be in the form of continuous sheet, feed-strip or pellets. The pumped polymer leaves through an outlet 9 against a smaller or larger resistance caused e.g. by a die-head, a screen or an inlet to another machine.

Passages 10 in the walls of casing 1 carry a tempering medium and similar passages or heating elements 11 in the walls of the channels 8 may be fitted to impart heat to the feed.

For each intake nip, there is at least one recess 13 in the direction of transport of the polymer in the walls of casing 1. Each recess 13 commences at zero depth at a distance above the nip-line of the gearwheels with the adjacent wall which is at least equal to the smallest width of the inlet channel 8, coming to a full cross-section at or beyond the nip and reducing to zero cross-section well within the transporting regions of the gearwheel. The recesses extend across substantially the whole width of the gearwheels and they may have different proportions of width to spacing. As indicated in Figures 3A and 4A, they may have a greater width than spacing, and in Figures 4A and 4B they may have substantially equal width and spacing.

In operation, the strip or sheet being gripped in the nip has continuous lengths of parts of its width moved through the recesses 13 beyond the nip into positions where the sheet between the recesses is already contained within the gearwheels and is there squeezed into the gearwheels whereby a cutting off of the feed strips or sheets at the nip is positively prevented.

Sets of recesses may be formed in casing inserts 14 or 15 which may be interchangeable to suit the flow- and/or plastification properties of the polymers or to be replaceable in case of wear. Preferably the inserts 14, 15 are heated, possibly to a higher temperature than the casing 1, on order to ensure a lower coefficient of friction for the material in the recesses.

In a modification (not shown) for oversized feed sheet, strip or pellets, the cross-sections of the recesses 13 taken together at their maximum exceed the volume of feed that can fill the gear teeth, whereby as the cross-section of said recesses reduces, the said gearwheels will tend to be

overfilled and entrained air and excess compound in a somewhat plasticized state moves up along the bottoms of the recesses to form, in advance of each nip and between the feed and the wall of the casing, the equivalent of a rolling-bank in an extruder. This serves to attenuate the supply of fresh feed towards a condition of equilibrium of intake and output while also expelling entrained air.

The embodiment of Figure 5 is a modification of Figure 1, in which one gearwheel of the gear pump, in this example the driven one 20, is of considerably larger diameter than the driving gearwheel 21. The casing 22 has passages 23 for a tempering medium, and the gearwheel 20 has a central passage 16 for tempering medium. Only the larger diameter gearwheel 20 has a feed inlet 24.

In an effort to extend the range of compounds for which they can be used, known gear pumps have feed devices such as a small two-roll mill, or a single roller on each intake, like the feed roller of an extruder, or a short preplasticizing extruder. These need additional drives and add to the mechanical complexity. These additional devices are eliminated by the invention in a surprising manner.

In Figure 5, if both gearwheels were separately fed through their respective nips as in Figure 1, both would transport the same amount of material regardless of their diameters, on account of their speeds of rotation being inversely proportional to these. However, the larger and more slowly rotating gearwheel will provide a proportionally longer residence-time for the material, which thus will be more exposed to heat transfer through the walls of the casing 22. Therefore at the outlet 25, here shown to be a passage of conical shape extending along the gears, the two streams of the material being pumped into it would be at considerably

different temperatures. To avoid this, the larger gearwheel 20 is provided with a feed inlet. The larger gearwheel 20 and the casing 22 then acts as a heat exchanger, and can be arranged to provide the correct amount of heat for the material being extruded.

Further, as the interaction of the gearwheels produce a high pressure at the outlet, even though no material is transported by the smaller gearwheel 21, and as the material is worked in producing this pressure, entrained air or gas liberated during heating of the material in the larger gearwheel 20 can escape to the inlet through the clearances between the smaller gearwheel 21 and the casing 22.

The inlet 24 to the larger gearwheel 20 is shaped as a duct extending substantially over the whole width of the gear pump so that the special preparation of feed may be simplified or dispensed with. Thus, depending on the size of the gear pump, sheet as it comes from the mill-room on pallets, mostly of width 800 mm and having more or less well-defined edges, or such sheet cut in half, about 400 mm wide, may be used, thus saving on cost of preparation of the feed.

The recesses 13 (like numerals indicating like parts as in the preceding drawings) then mainly serve the purpose of positively avoiding such feed being cut-off at the nip, although the formation of a rolling bank could also be involved. As a single sheet of material may have major holes or tears, the rolling bank may not be continuous, and air may be entrained. However, entrained air will be expelled through the smaller non-fed gearwheel 21 into the feed inlet 24, on account of the material being compressed at the meshing region of the gearwheels. The outlet 25 serves to convey the material under pressure axially of the gear pump into an outlet leading to a screen, an extrusion head or the like or to a coaxial

extruder, preferably of the Transfermix type. This integral extruder then serves to impart to the thermally prewarmed polymer whatever amount of mechanical working it can still absorb on account of its viscosity, i.e. less for a soft polymer and more for a tougher polymer characterised by "nerve" or a corresponding molecular structure or a high loading of filler, and can also homogenise the temperature.

Owing to the large diameter and width of the gear and by way of setting the temperature of the heating medium, it will be possible to vary the temperature of the polymer coming into the extruder to suit its viscosity and flow characteristics to such a level that the mechanical work-input will neither be insufficient nor excessive by any significant amount. This can especially be achieved with a Transfermix geometry which, with appropriate design, will uniformly impart mechanical work to all of the polymer even when the speed of rotation of the screw is slow compared to extruders not fed by a gear pump.

A simple calculation of continuity will show that, for example, a 200 mm Ø extruder fed by a sheet of width 800 mm and thickness 8 mm with a specific gravity of 1.15, drawn in at the circumferential speed of the rotor, will transport at the rate of 280 Kg/rpm/hr. This amounts to an output of 2800 Kg/hr for a rotor (and screw)-speed of 10 rpm.

A modern pin-barrel extruder will provide this order of output as a maximum at 30 rpm, at still acceptable extrusion temperatures which are a direct function of the screw speed. This applies to that range of compounds which the pin-barrel will still satisfactorily plasticize, i.e. extrude without cold lumps, a rough surface (orange-skin), dimensional instability, etc. At this time this excludes, for example, certain types of highly loaded Natural Rubber Compounds which are used in truck-tyre

treads which represent a sizeable tonnage of rubber used in the industry and for which hot-fed extruders preceded by prewarming mills are still in common use. It is such a draw-back which this invention overcomes in a surprising manner. A directly fed gear pump pressure-feeding into a Transfermix extruder comprising a plasticising length of about two diameters length without any additional length for pressure buildup, will thus make for an overall length of the order of 6 diameters including the feed inlet. It will thus provide a surprising advantage of size and complexity as well as of energy-requirement over a conventional extruder having a feed inlet requiring a feed-roller and providing much wasted mechanical energy by regurgitation there and in the compression-section besides having about double the length overall. Thus an additional energy-saving on mechanical work-input and saved heat-losses is provided. As compared to a conventional Transfermix, it will also save the mechanical complexity of an adjustable throttle.

It will be understood that the gearwheels forming the pump may have their teeth parallel to their axes, or may have these skewed in one way or arrow-fashion to promote self-cleaning and a smoother pumping action. Also, portions of the housing may be openable for ease of cleaning when the compound is changed.

Moreover, in an embodiment such as Figure 5, both the larger and the smaller gearwheels may be driven directly by appropriate shafts extending from a mechanical gearbox having the same size gearwheels for the mechanical force-transfer. In such a system, actually mechanically redundant, the oil-lubricated gears in the gearbox will be designed to override the forces in the gear pump. In this case, for elastomers, which are much more viscous than plastics melts and require lesser pressures

when used as filament pumps, the pumping gears may have greater tolerances than driving gears.

Figure 6 shows an embodiment similar to that of Figure 5 in the gear pump part, except that here the driving gear is 30 with the larger diameter and the driven one 31 is the smaller one, also moved angularly so as to accommodate the end channel 33 extending in a substantially tangential direction of the larger gear. That part 34 of the housing 22 which envelops the smaller gear is separate, being hinged at 35 to be openable for cleaning. The closure and locking mechanism, 36 not shown in detail, has to be made of substantial strength to be able to withstand and seal against the substantial pressures produced by the gear pump. Such mechanisms are known in the art e.g. for extrusion-heads made openable for cleaning.

At the circular outlet flange 37 of the outlet, a screening device pack or an extrusion-head may be provided in a known manner for these materials which may have been sufficiently plasticized by the action of the gear pump. A *screening device with its* breaker plate *and* screens already materially contributes to such plasticization.

There is, however a range of polymers for which this will not be the case or for which screening is not necessary or even desirable, such as certain natural rubber compounds whose "nerve" contributes to properties of wear-resistance. For these, the invention provides a Transfermix 38 to fit between outlet flange 37 and an extrusion head 39. Although this will generally be longer than a screening device, it can be handled in a similar way to a screening device for assembly and disassembly - for instance like a swing head, whose vertical support axis 40 may also serve for the

extrusion swing head 39, if the parts are of a size to preclude moving by hand.

The Transfermix shown separately in Figure 7 has helical stator-threads 41 and an interior component 42 which may also be stationary or be a rotor with opposite handed helical threads 43, as seen in the partial section taken on the conical interface 44.

The interior component 42, if built to be rotated is not provided with an external drive, but will be rotated by the stream of elastomer under the pressure provided by the gear pump. The energy absorbed will be exactly that required for the remaining plasticization of the material on being transferred from the stator to the rotor, so that the action is optimally energy-conserving.

The rotor can be mounted on an internal spindle (not shown) fixed to a spider 45, the axial thrust-bearing being mounted at the end of this spindle in the region of the nose-cone 46 of the rotor and any radial bearing nearer the spider.

It is known that a Transfermix geometry mixes also when consisting solely of stationary components and this option is also provided in this invention for the limited range of media which this arrangement will serve.

As this Transfermix is built to be externally similar to a screening device, and is mounted in place of such a device, cleaning will be carried out similarly by quick disassembly and taking out of the pieces of elastomer or plastic remaining in the Transfermix and in the transition passage between parts 323 or 33 and the outlet flange 37 of the pump. As the

Transfermix has no screening function, it cannot get clogged up with dirt, and cleaning will only be necessary when production has to stop. For this purpose also the Transfermix internal components can be taken apart out of the outer component 41.

Figure 8 shows an alternative shape of gear wheel configuration which is intended to provide a larger quantity of material in the larger diameter gearwheel 50, which is effective in heat transfer, and correspondingly less in the smaller gearwheel 51.

For the sake of convenience, this is here shown for the big wheel 50 by leaving out every second gear tooth to form a wider groove 52 which in its turn engages with a wider tooth 53.

Generally, one can conceive of different gearing geometries which provide a line-contact which continuously moves round the outlines of both gearwheels at the nip to provide the pumping action. This is likely, however, to operate to the disadvantage of the torque-transfer function, i.e. the driving of one gearwheel by the other.

This potential disadvantage can be conveniently overcome by the gear geometries here described, where at both edges or alternatively in the middle of their lengths both gearwheels may be provided with a narrower width than the original geometry, as indicated at 54 and 55 in dotted lines. Thereby regular driving will be realised and proper engagement of the special profiles will be assured.

Moreover, as the driven gearwheel has no function other than that of a moveable barrier at the nip, which requires little torque, it is conceivable to let the smaller gear wheel run without a shaft and bearings. This

would eliminate any sealing problems of these components. The gearwheel then would be centred by its cylindrical housing. In favourable circumstances, enough material would be drawn in between the outer surface of the gear teeth and the wall of the casing to provide for lubrication by the material. This works in many gear pumps, even for elastomers in the shaft bearings and is effective as long as continuous "bleeding" of the medium is provided for. For suitable materials, this is likely to be the case for the smaller gearwheel even though it is not being fed a medium. The formation of a lubricating film will be aided by a small chamfer at the leading edge of the teeth of the non-fed gearwheel.

The invention includes the provision of a Transfermix device which is not driven by an external motor, or has no rotatable component in place of a screen device for gear pumps of any type presently in use, not just that described with reference to Figure 6.

Figures 9 and 10 show a pump with a large gearwheel 60 and a smaller gearwheel 61 in a casing 62, which is provided with passages 63 for a heating/cooling medium and with a vertical inlet duct 64 for feeding material into the single nip formed between the large gearwheel 60 and the wall of the casing 62. The material may be pellets, an irregularly shaped drop from an internal mixer or flakes still containing residual moisture from a drier, for example. The outlet 65 has its axis running substantially in the same direction as the axes of the gearwheels and is of nearly conical shape, opening up into the barrel-section of a Transfermix extruder 72 with its screw 71 on the same shaft as the small gearwheel 61 and driven by means of the gear-box 73. Over its length, the characteristic Transfermix configuration provides for opposite-handed screws, where in the barrel 74 the flow-cross-section changes from a full value to zero while in the screw 75 the flow cross-section changes from

zero to a full value.

The gearwheels 60 and 61 are cut in arrow-fashion such that, as they rotate, the material within the gear teeth is moved towards the centre and away from the end-plates 76 and 77 of the gear pump. Channels 78 (shown dotted in Figure. 10) are provided in these end-plates, leading from the region of pressure buildup to the inlet 64 as an area of low pressure. Thereby degassing additional to that via the non-fed gearwheel 61 can occur. Where suitable to the application, vacuum may be applied to the inlet in order to improve the degassing overall.

The embodiment of Figure 11 is similar to that of Figures 9 and 10 except that the small gearwheel 81 is in a different arrangement relative to the large gearwheel 80, in order to provide space for a still wider drop shaft 84 for the feed and a separate duct 85 for exhausting gas, air or steam under vacuum. Otherwise like numerals denote like parts. An additional feature here is a sealing pad 86 between the exhaust duct 85 and the inlet duct 84. This may be made of abrasion-resistant rubber or a similar compound such as is used for cladding the insides of ball-mills used for grinding rocks. The proviso here is that the minor quantities of rubber abraded do not contaminate the product being processed by the gear pump. Means (not shown) may be provided to keep up a required pressure of the sealing-pad 86 against the smaller gearwheel 81, e.g. by a spring or pneumatically. Channels 79, similar to channels 78 in Figure 10, are provided in the end-plates of the gear pump which lead from the pressure buildup region to the exhaust duct 85, for additional degassing.

Figure 12 shows the flow-lines on the pressure-side of a conventional gear-pump, for the better understanding of the embodiments shown in Figures 13 and 14. Figure 12 has been adapted from

"*Zahnradschmelzepumpen in der Extrusion: Prozessanalyse und Möglichkeiten zur rechnergestützten Auslegung*" or "Gear-Pumps for Polymer-Melts in Extrusion and the Possibilities of their Computer Aided Layout" December 1992, IKV (Institut für Kunststoffverarbeitung) of the RW Technical University, Aachen, page 45, Figs. 3.3b. Here flow lines determined by experiment and by calculation respectively are shown to be in good agreement.

The drawing is a section of the pressure buildup region and the outlet of a gear pump with equal gearwheels 91 and 92, both fed with the material, in a casing 90, with the ends 93 and 94 of the outlet which is arranged symmetrically about the common tangent 89 to the pitch-circles of the gearwheels being shown in line with the full diameter of the outlet.

Considering these flow-lines in relation to the effectiveness of a pump for e.g. elastomers having even considerably higher viscosities when plasticized than a plastic melt it may be concluded that that the spaces 95 and 96 of the gearwheels might just as well be covered by inward extensions of the casing parts 93 and 94, as there are no forces which make any material emerge from spaces 95 and 96 into the outlet.

Pressure buildup occurs only in the space 97 of the lower gearwheel 92 as the upper gear tooth 99 enters into it and the material cannot escape into the spaces where the gear teeth practically already interlock. As rotation proceeds one space further round, the same applies for the corresponding space 98 in the upper gearwheel 91.

Figure 13 shows a projected flow for the embodiments according to this invention, where a single gearwheel, in this case the lower gearwheel 92, is being fed. Here the pressure buildup can only occur when the space 98

in the upper gearwheel has been filled with material being squeezed out of space 97 by the upper gear tooth 99 entering space 97. If the edge of the casing 90 is like that shown at 94 in Figure 12, space 96, would also have to be filled up before any pressure buildup can be effective. In order to avoid this, the edge 100 projecting towards, or even up to, the common tangent 89 of the pitch-circles is provided in this embodiment.

Figure 14 shows, as a further variation, that the edge 100 of the casing has a by-pass 101 cut into it whereby the space 96 is filled in advance of its rotation into the engagement or pressure buildup region. Then the pressure buildup can proceed analogously as in Figure 12 where both gearwheels are filled with the medium and the degassing action past the non-fed gearwheel 91 will then proceed from space 96.

To improve the transport out of the fed lower gearwheel 92, the lower edge is here shown as 102 in a corresponding shape as the upper edge 100.

It must be realised that Figures 13 and 14 are sections in one plane only and that, dependent on how well the lower gearwheel is filled, other sections may show voids or air inclusions. The provision of the by-pass 101 in Figure 14 will serve to completely fill these up. In order to achieve this, it will not be necessary for the by-pass 101 to cover the complete width of the gearwheels. This is because space 96 is originally empty and capable of venting towards the inlet 64 and/or to the exhaust duct 85 and the material coming into this with the full pressure buildup, will fill this space 96 up over the complete width. In the pressure buildup region both spaces will then be filled by direct interaction. The by-pass 101 might therefore consist of two short passages placed about the middle of the width or of one central passage or even a grid to aid in opening up the

flow of polymer for gases to emerge. The by-pass 101 may be provided in a separate insert 103 into the casing 90. Several inserts with different dispositions of by-passes may be provided to be interchangeable in casing 40.

It will be appreciated that the escape channels or the by-pass could also be provided in the embodiments of Figure 5 and 6.